α_S in e^+e^- collisions at LEP and JADE

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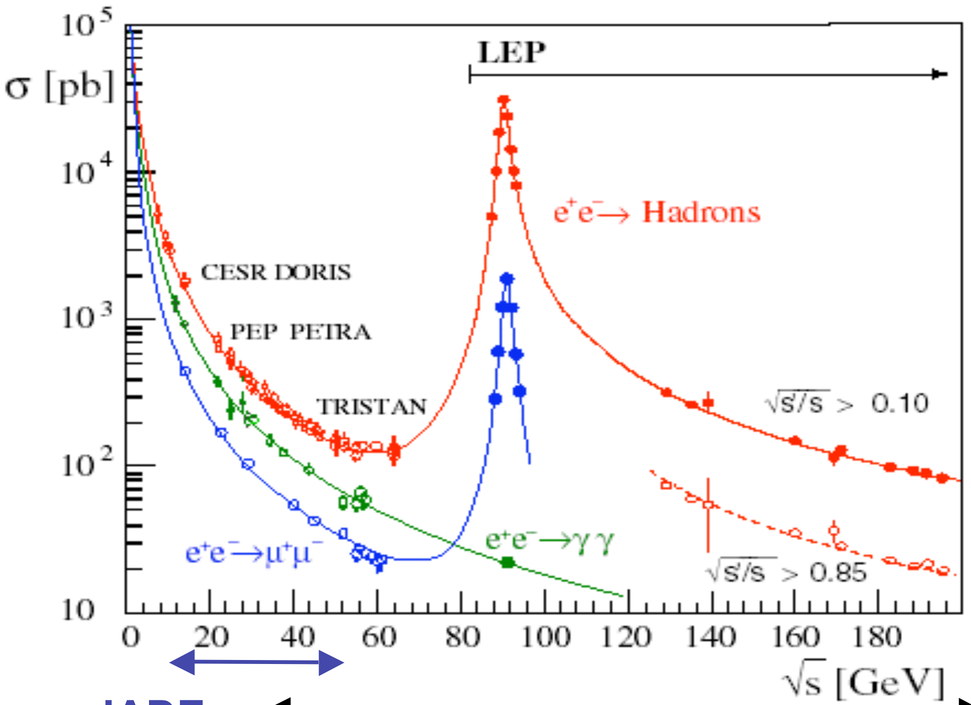
submitted papers:

1. **L3, Studies of Hadronic Event Structure in e+e- Annihilation from 30 GeV to 209 GeV with the L3 Detector, Phys. Rept. 399:71 (2004)**
2. **OPAL, Determination of α_S Using Jet Rates at LEP with the OPAL Detector, EPJ C45: 547 (2006)**
3. **OPAL, Measurement of the Strong Coupling α_S from Four-Jet Observables in e^+e^- Annihilation, accepted by EPJ C**
4. **JADE, Measurement of the Strong Coupling α_S from Four-Jet Observables in e^+e^- Annihilation using JADE data, accepted by EPJ C**

e^+e^- Data Sample



JADE
(14-44 GeV)

LEP
(30-86; 91-209 GeV)

	energy range [GeV]	events per energy point
JADE	14-44	1k – 20k
LEP	30-86*	1k-3k
	91	> 100k
	130-209	0.5k – 5k

* radiative return events

•assumes factorization gluon from photon production (Dasgupta, Salam : hep-ph/0312283)

•JADE (14-44 GeV): $b\bar{b}$-events subtracted

•LEP I (91 GeV): no background

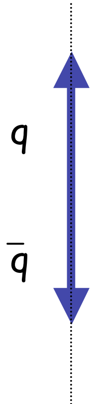
•LEP I.5 (> 130 GeV): radiative return events subtracted

•LEP II (>160 GeV): W^+W^- events subtracted

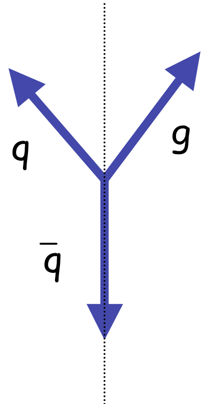
Measurement of α_S using Event Shapes

- size of α_S proportional to the number of radiated gluons
- gluon radiation pictured by event shapes variables

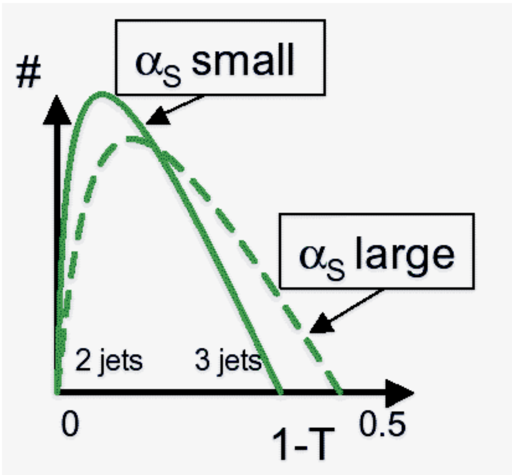
e.g. Thrust: $$T = \max_{\vec{n}} \left(\frac{\sum_i |\vec{p}_i \vec{n}|}{\sum_i |\vec{p}_i|} \right)$$

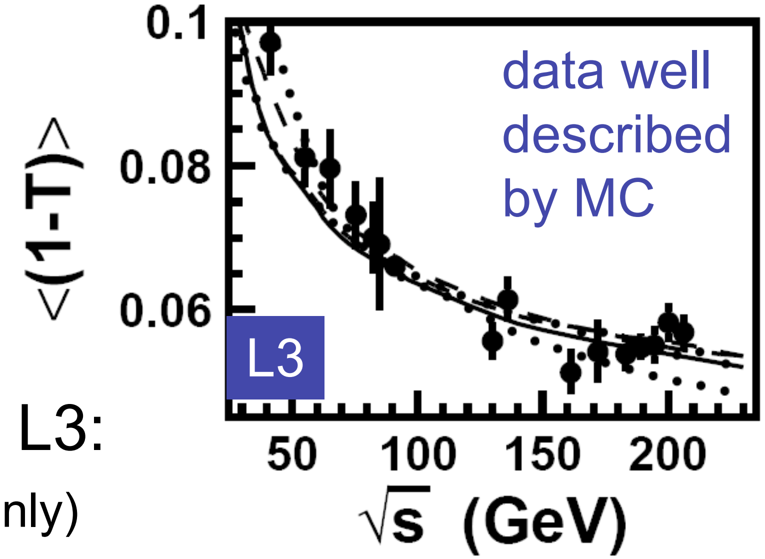


1-T=0



1/3>1-T>0



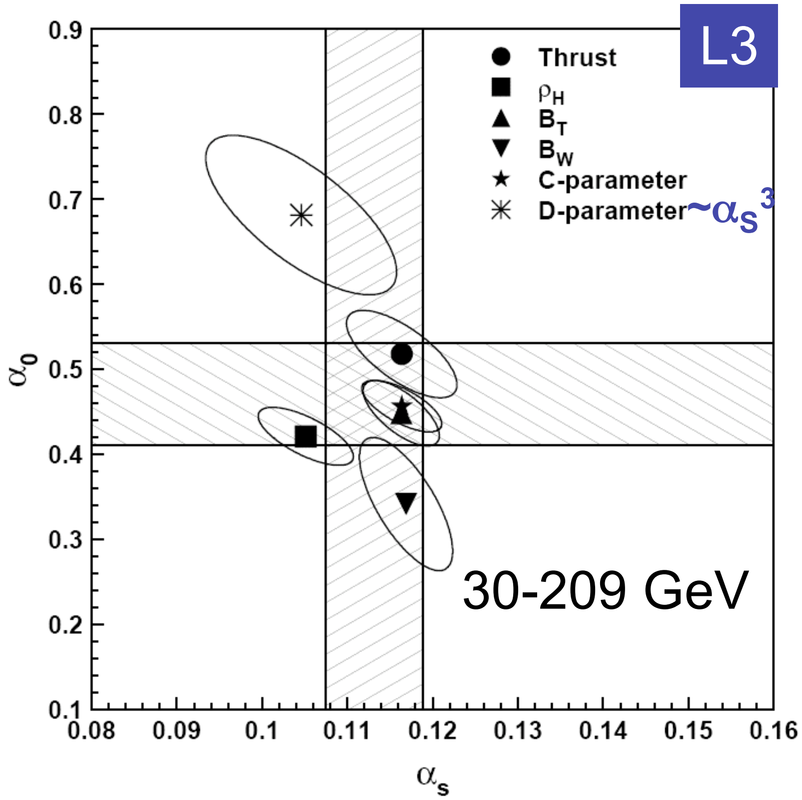


event shapes observables used by L3:
1-T, C, B_T, B_W, y_{23}, M_H (and D, mean only)

Hadronization with Power Corrections

- determine 1st moment of event shapes
  - mean value $\langle F \rangle = \int F \frac{1}{\sigma} \frac{d\sigma}{dF} dF$
  - sample full region of phase space
- QCD predictions at parton level (NLO)
- apply hadronization correction
  - Power Corrections: DMW approach, hadronization corrections described with single parameter α_0
- confidence level for common α_0: 1% (stat. only)

(DMW: theoretical uncertainty ~20%)

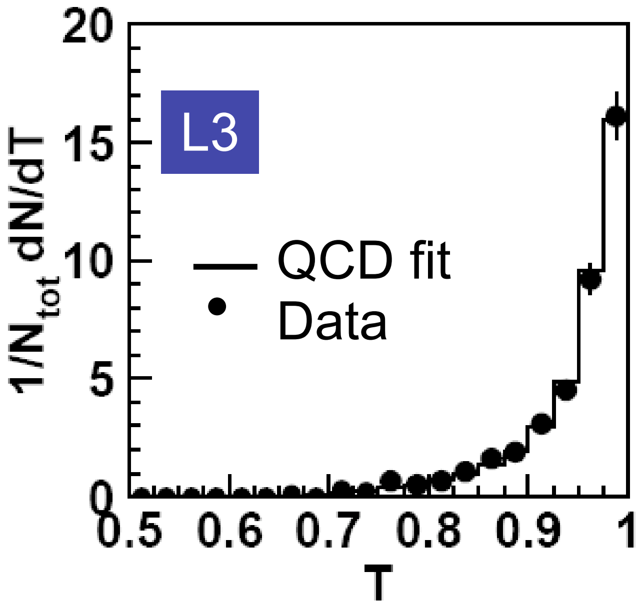


α_s= 0.1126±0.0045±0.0039
α_0= 0.478±0.054±0.024

(stat±systematic)

Hadronizaton using Monte Carlo Models

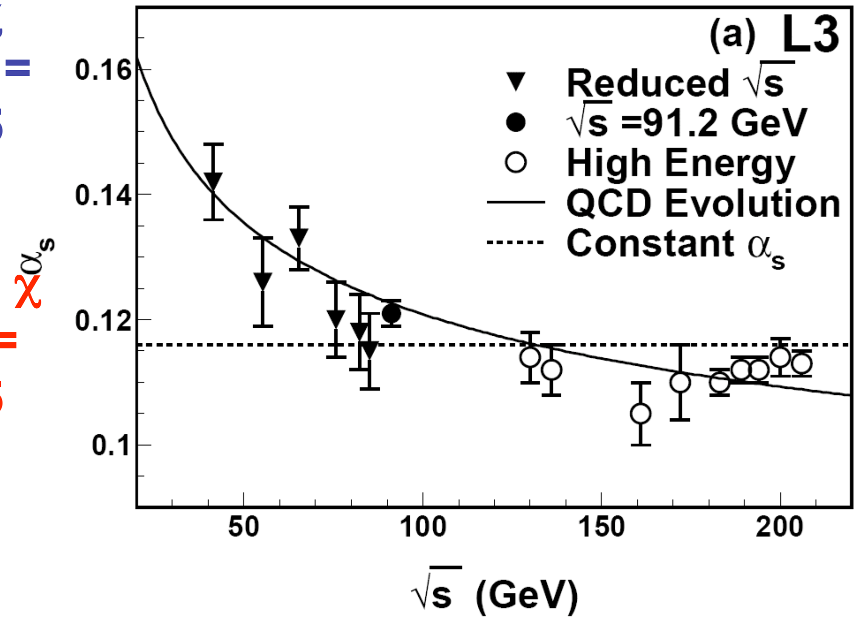
- apply fit to event-shape distribution **(only part of the distribution fitted)**
- describe hadronization correction with Monte Carlo models
- resummed calculations (NLO+NLLA)



$\sqrt{s}$=202 GeV

QCD: χ^2/d.o.f. = 17.9/15

const.: χ^2/d.o.f.= 51.7/15



α_s= 0.1227±0.0012±0.0058

(exp±theo)

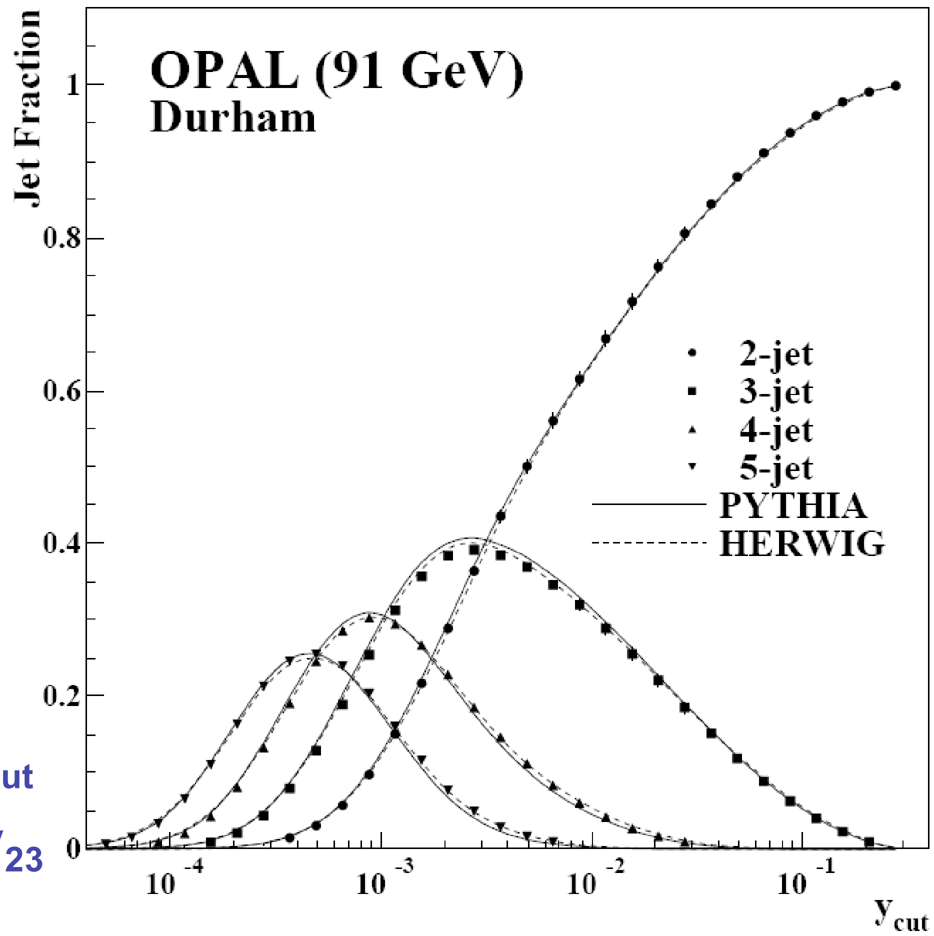
Measurement of α_S using Jet Rates

number of jets reflects strength of the strong coupling α_S

- cluster particles according to jetfinder scheme:
  - Cambridge
  - Durham:

$$y_{ij} = \frac{2\min(E_i^2, E_j^2)}{E_{vis}^2}(1-\cos\theta_{ij})$$

- combine particles with smallest y_{ij}



- **number of jets as a function of y_{cut}**
- **number of events with a certain y_{23}**

Measurement of α_S using Jet Rates

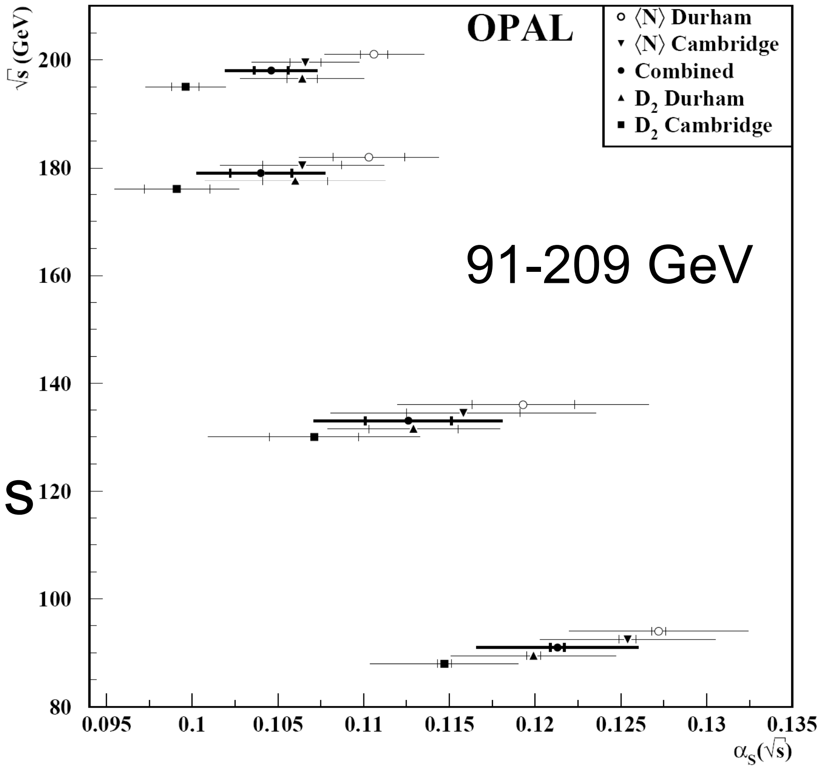
- average jetrate

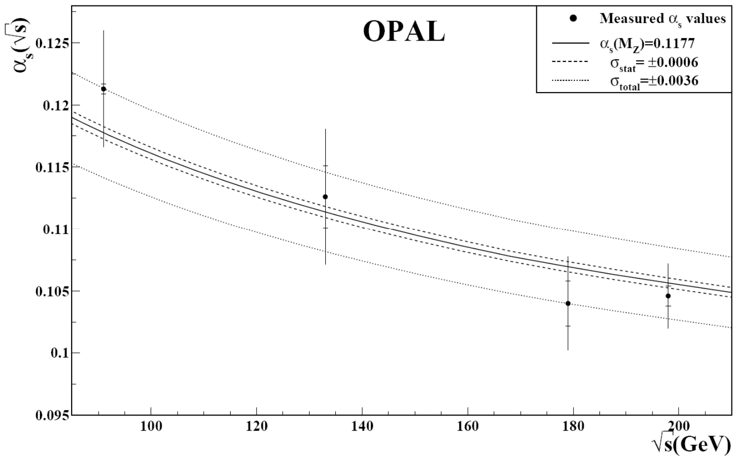
$$\langle N \rangle (y_{cut}) = \frac{1}{\sigma_{tot}} \sum_n n \sigma_n (y_{cut})$$

- differential 2-jet rate y_{23}

apply NLO+NLLA QCD calculations

$R_3 = \alpha_S A + \alpha_S^2 B + O(\alpha_S^3)$+NLLA terms





α_s= 0.1177±0.0006±0.0012±0.0010±0.0032

(stat±exp±had±theo)

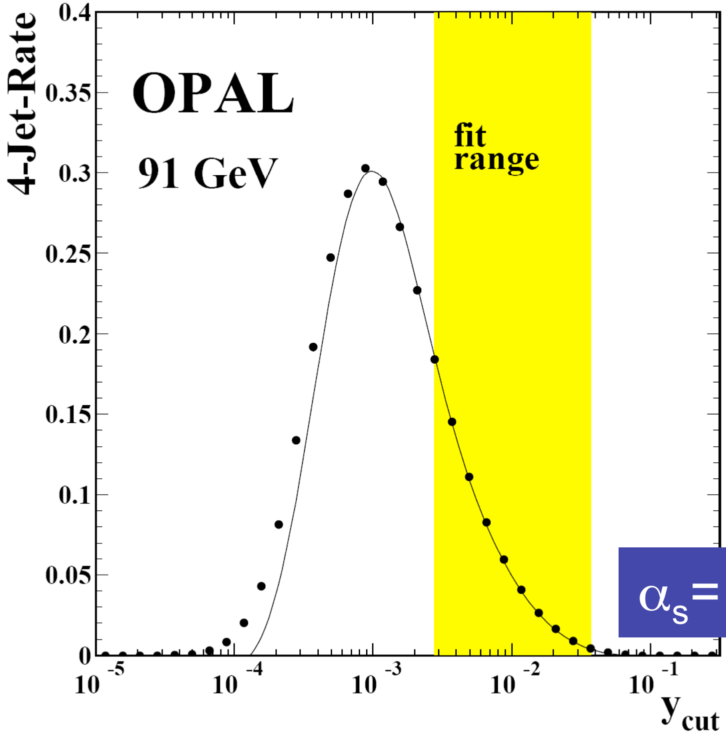
▶ uncertainty dominated by theory

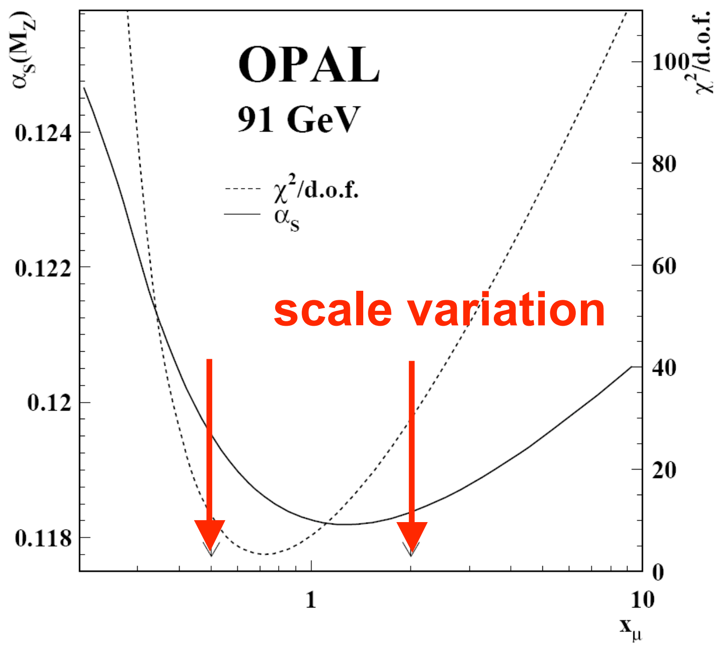
Measurement of α_S using Four-Jet Rate

leading order prediction four-jet rate ~ α_S^2

$R_4=\alpha_s^2 B + \alpha_s^3 C$ +NLLA terms

reduced scale sensitvity: $\Delta R_4(x_\mu) \propto \alpha_S{}^3 \cdot \ln x_\mu$





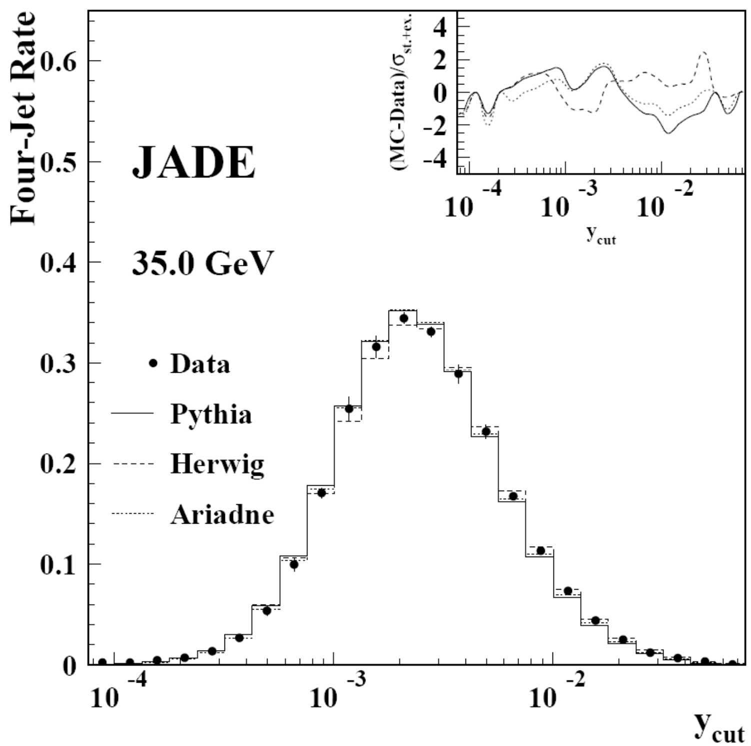
natural scale x_μ=1 close to minimum
➔ reduced scale senistivity

α_s= 0.1182±0.0003±0.0015±0.0011±0.0012±0.0013

(stat±exp±had±theo±bmass)

Measurement of α_S using Four-Jet Rate

- resurrection of data taken with the JADE detector allows unique access to e^+e^- data taken at 14 GeV $\leq \sqrt{s} \leq$ 44 GeV

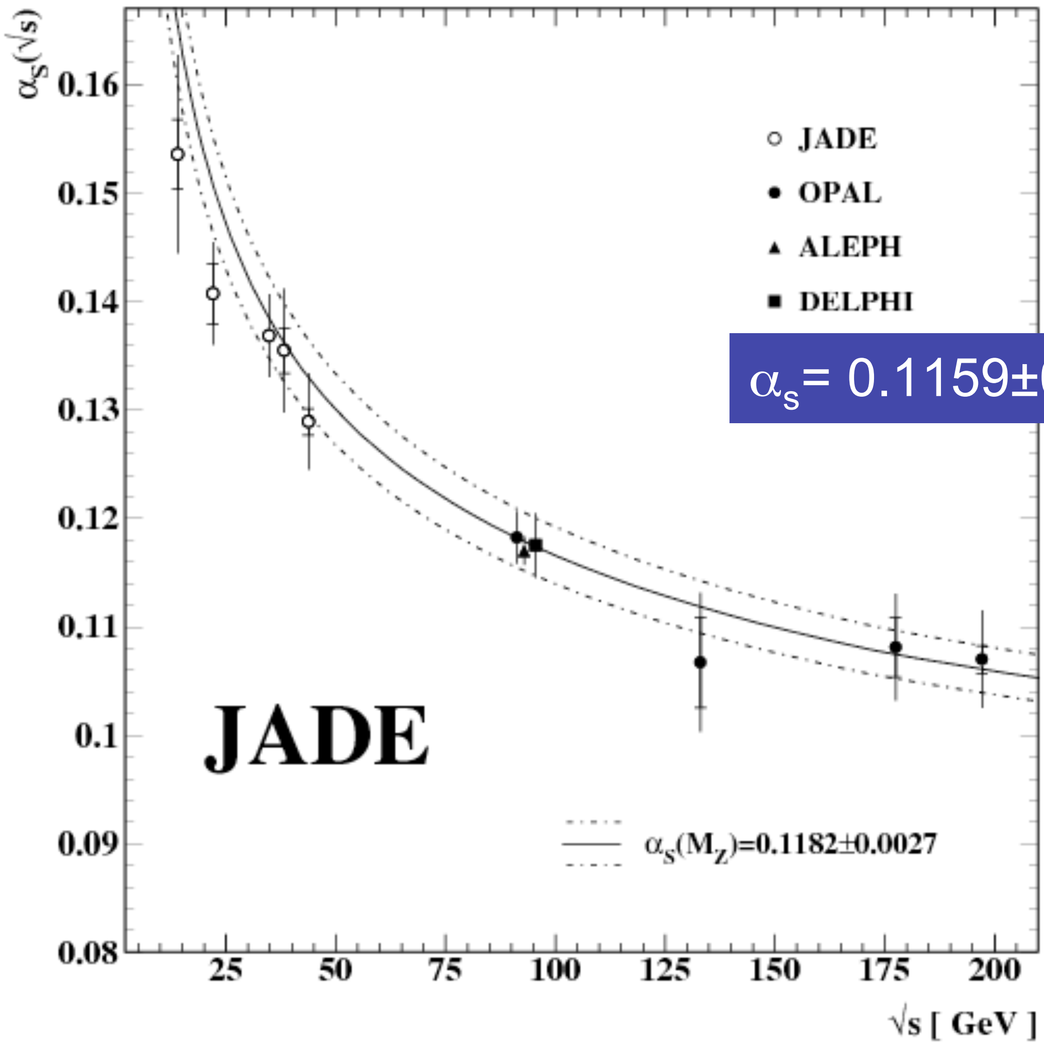


•more than 40k multihadronic events

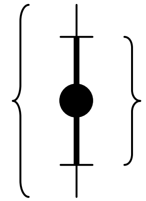
•data well described by Monte Carlo models tuned at LEP 1 (OPAL)

►similar sensitivity to α_S like LEP measurements

Measurement of α_S using Four-Jet Rate



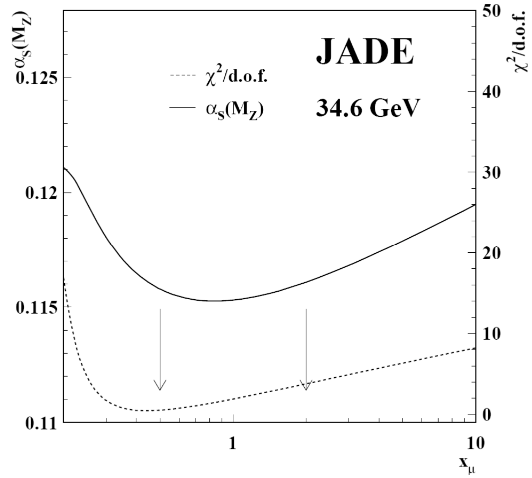
total. error



stat. error

α_s= 0.1159±0.0004±0.0012±0.0024±0.0007

(stat±exp±had±theo)



Running of Strong Coupling α_S

	running α_S χ^2/d.o.f. χ^2 probability	constant α_S χ^2/d.o.f. χ^2 probability
JADE 14-44 GeV	3.9/5 57%	7.0/5 22%
OPAL 91-209 GeV	6.4/12 90%	12.4/12 42%
JADE+OPAL 14-209 GeV	12.0/18 85% α_S=0.1168±0.0024	149.5/18 9 x 10^{-21} % α_S=0.1227±0.0025

combination of α_S values using description of LEP QCD WG

- JADE data alone return no significant proof for running of α_S
- LEP alone consistent with being constant

►combination of LEP and JADE date confirms running of α_S with high significance

Measurement of α_S using Event Shape Observables ~ α_S^2

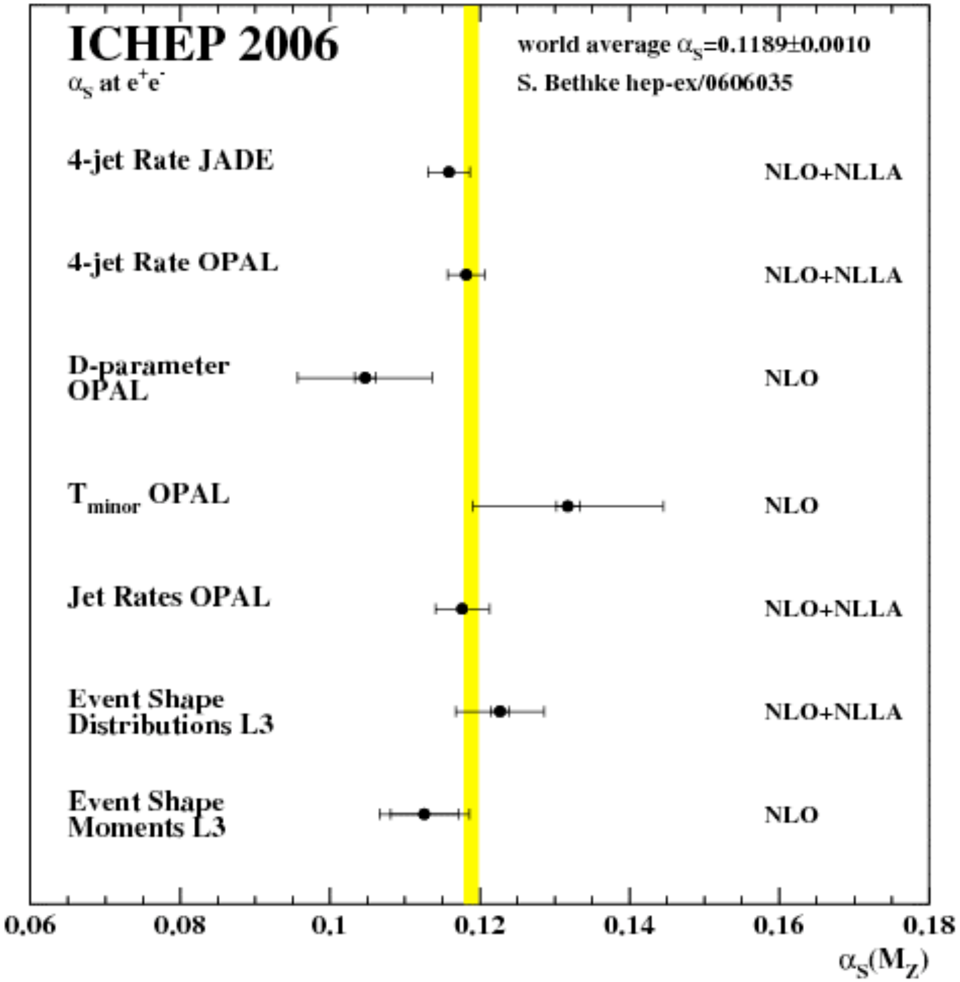
perturbative predictions for D-Parameter and T_{Minor} only available in NLO

- no resummed calculation available
    - data not well described
    - increased scale sensitvity

D-Par: α_S= 0.1047±0.0014±0.0088
T_{Min} : α_S= 0.1318±0.0016±0.0126

(stat±syst.)

Conclusion



- still ongoing QCD analysis at LEP
- all measurements return values of α_S consistent with the current world average
- α_S determined from the four-jet rate leads to smaller scale uncertainty
- LEP and JADE data combined confirm running of α_S with high significance